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INDOOR SWIMMING POOLS

HUMIDITY CAUSED PROBLEMS AND SUGGESTED SOLUTIONS

ISRC Facility Subcommittee

National Research Council

Institute for Research in Construction

Foreword and Acknowledgement

Reports have been received from across Canada on premature deterioration of indoor pool and arena buildings. The following technical paper was prepared to assist pool managers to start to solve their common problems. It identifies the likely causes of various humidity-related problems and suggests possible solutions. This report is not, however, a substitute for professional advice. Architects, engineers or other building professionals should be consulted.

This technical paper on pools and its companion volume on arenas, "Indoor ice arenas - humidity-caused problems and suggested solutions," are the results of a partnership between the:

Interprovincial Sport and Recreation Council,
Facilities Subcommittee,
National Research Council of Canada, Institute for Research in Construction,
Ontario Ministry of Tourism and Recreation,
Alberta Recreation and Parks and
Presidents of provincial facility associations from across Canada.

Principal research and writing for these manuals was completed by Charles S. Strelka, P.Eng., MRAIC, National Research Council, Institute for Research in Construction. Anne Zavaros, University of Waterloo, provided editorial comments and the Ontario Ministry of Tourism and Recreation acted as a project manager. Alberta Recreation and Parks kindly arranged for printing and distribution.

A special thanks is due to the many recreation facility professionals and others who reported on humidity problems they had encountered as well as reviewing earlier drafts of the manual.

Please provide your comments, experiences or suggestions for humidity control to:

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I) INTRODUCTION

Most municipally owned, indoor swimming pools were constructed in the 1960's and 70's, during the "golden age" of recreation funding. Today, after 15-20 years of operation, inadequate design and/or construction, and heavy use combine to make operational problems more pronounced and unacceptable to even the most tolerant user.

The problems encountered span the field of building operation - from leaking roof to deteriorating exterior wall. Many of these problems are interrelated. The visible problem, for instance rusting metal doors and lockers, may cause the owner/operator to blame the quality of the last year's painting job when in fact, the high cost of maintenance is caused by high humidity in the pool space. The humid air causes moisture to condensate on any cool surface gradually ruining the paint and ultimately, the structure itself. Moisture condensation is the most frequent cause of problems encountered.

In the course of a preliminary study conducted in the fall of 1985, we were able to examine several recreational buildings in various stages of disrepair. For owners/operators, who face a similar situation, this report will attempt to describe the most frequent problems, state the causes, and suggest possible solutions. Where remedial action was taken, information on results will be included.

II) INDOOR SWIMMING POOLS

Indoor swimming pool building structure is exposed to high indoor air humidity. Problems caused by the humid environment are complicated further by the presence of chlorine vapours in the air. The chlorine, evaporating into the air from the pool water, increases the corrosive action of moisture condensed on the cold surfaces of the building structure or on metal interior furnishing (Figure 1).

III) TYPICAL INDOOR SWIMMING POOL BUILDING

A typical indoor swimming pool building we have observed had an exterior wall consisting of concrete blocks on the interior side, rigid insulation in the wall cavity and exterior facing of bricks or concrete blocks. The roof bearing structure consisted of steel columns, either embedded in the interior concrete block part of the wall or exposed on the interior side, carrying perimeter steel beams. The perimeter beams in turn supported the steel roof trusses and joists. The metal roof deck or wood roof over this bearing structure was insulated on the outside as part of the roofing system (Figures 2 and 3).

IV) TYPICAL PROBLEMS REPORTED BY THE OWNERS/OPERATORS

Problem 1 The roof leaks, water is dripping into the pool and in some cases contaminating pool water.

Problem 2 Condensation is forming on the inside face of exterior walls.

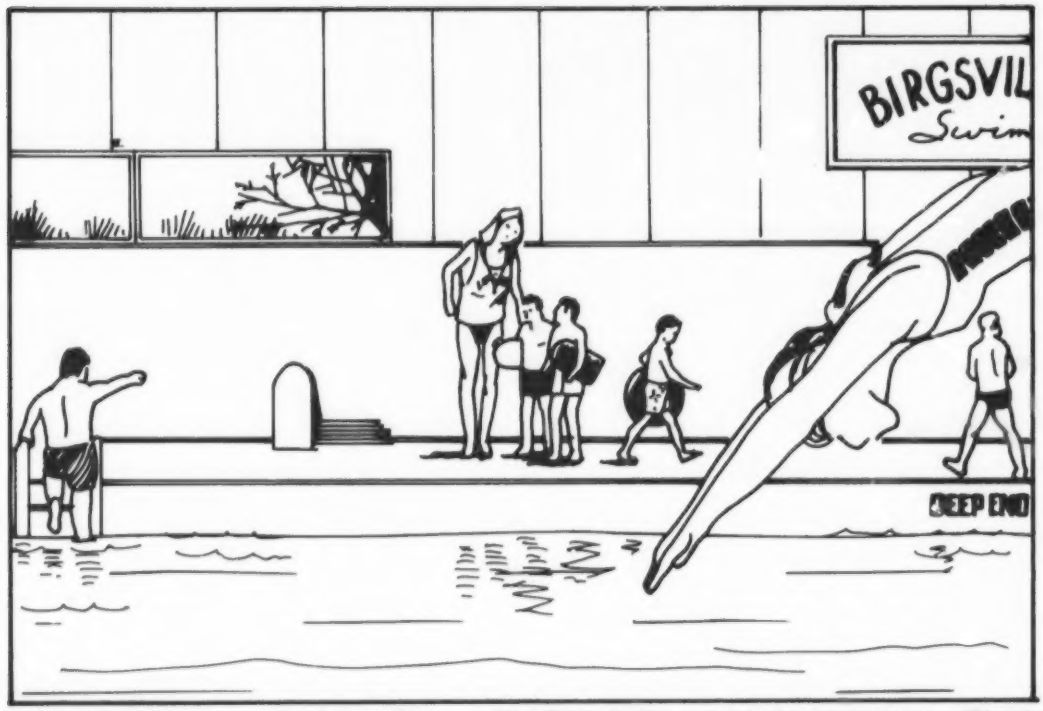

FIGURE 1. TYPICAL INDOOR SWIMMING POOL

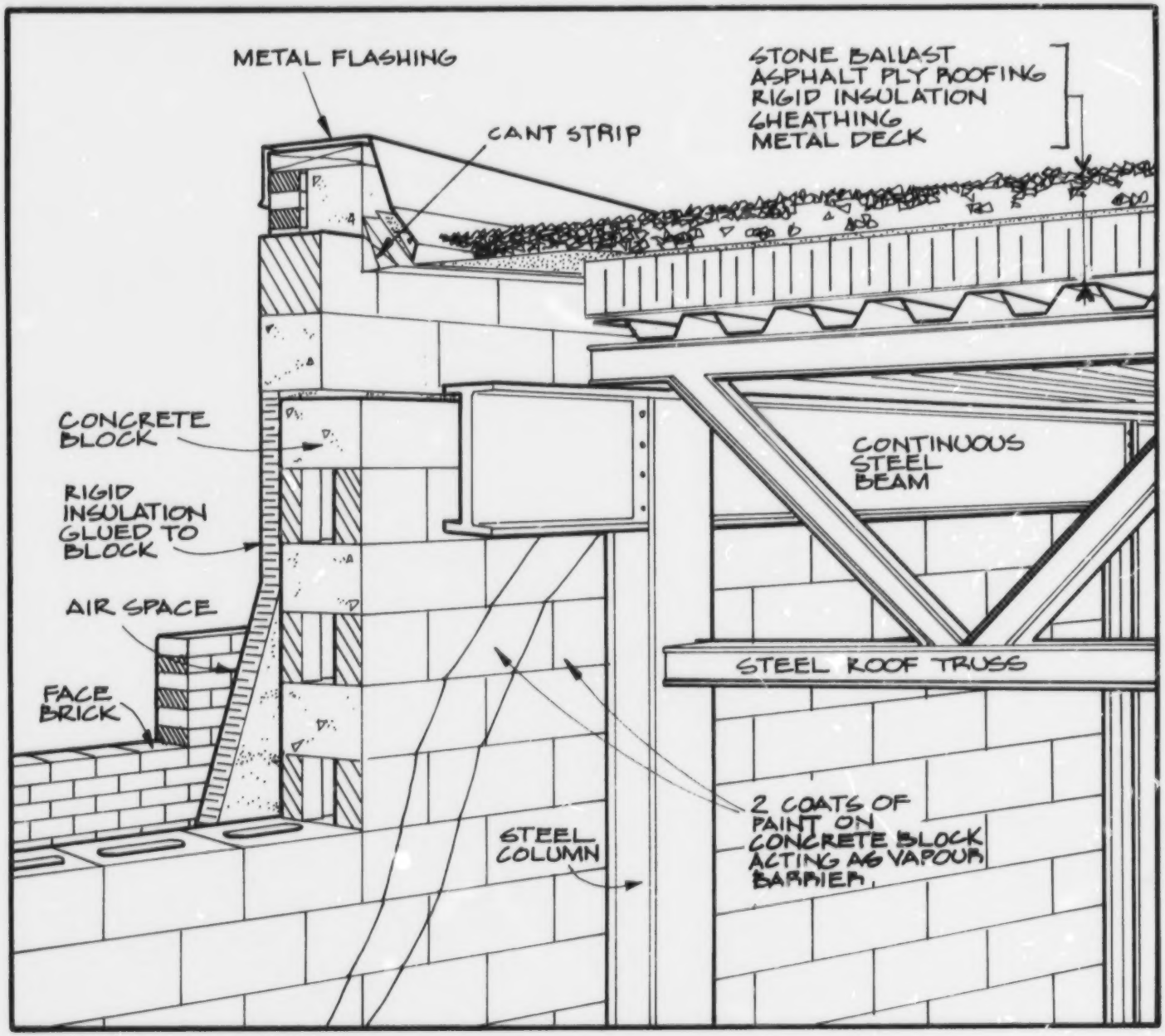

FIGURE 2. TYPICAL POOL BUILDING EXTERIOR WALL - UPPER PART

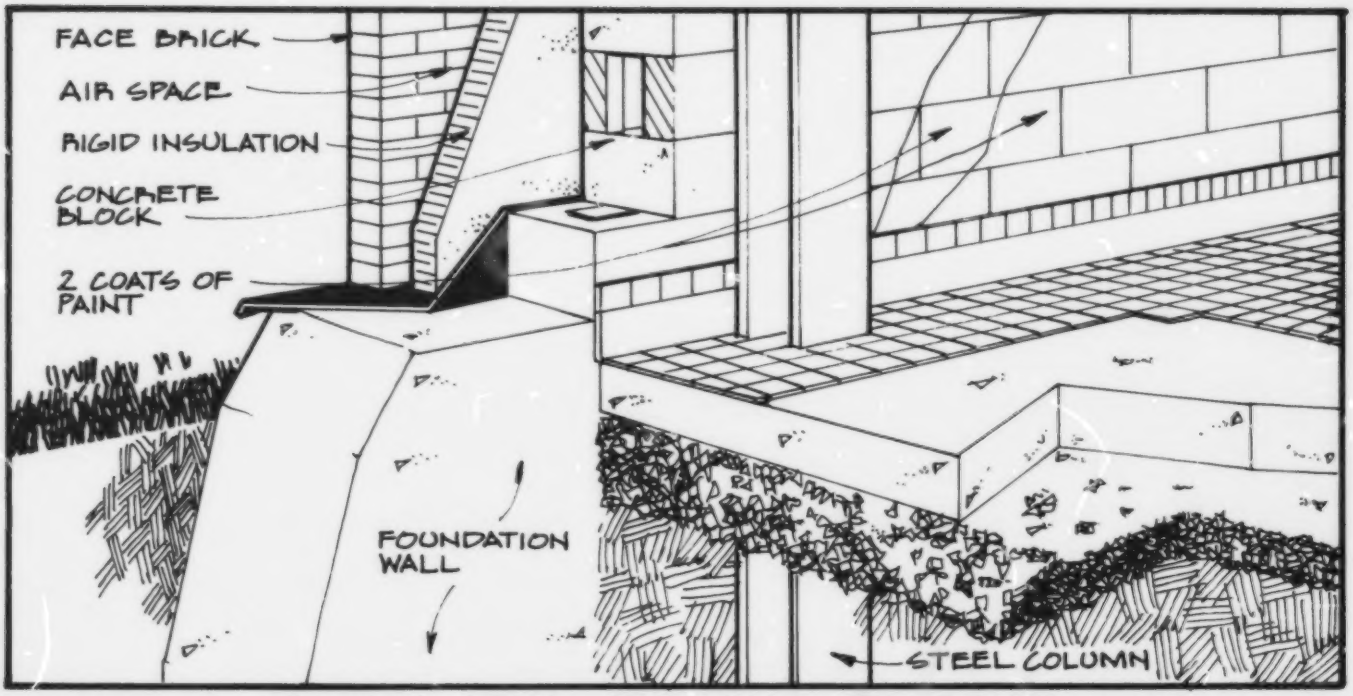

FIGURE 3. TYPICAL POOL BUILDING EXTERIOR WALL - LOWER PART

Problem 3 Interior paint is peeling.

Problem 4 Concrete blocks at the pool deck level are falling apart.

Problem 5 Heavy efflorescence is forming on the exterior of the building and the exterior brick or block facing is spalling.

Problem 6 Metal elements (doors, door frames, window frames, diving tower structure, roof structure) are rusting. This happens even in parts of the building other than the swimming pool hall itself.

Problem 7 The cost of heating pool water is high.

V) DISCUSSION OF THE PROBLEMS REPORTED

a) Problem 1 - Leaking Roof, Water Dripping into the Pool

The roofing system over a swimming pool enclosure is exposed to higher thermal stresses than a roof over a warehouse of the same floor area. The warm, humid environment of the pool hall introduces moisture in the form of water vapour into the roofing system by any minute opening in the structural and in the air/vapour barrier. The water vapour, in combinati with the air trapped between the air/vapour barrier (next to the steel or wood deck) and the continuous roofing membrane on top of insulation, expands during the warm periods of the day and contracts during cold nights. Where there is an air pocket or insufficient adhesion between the roofing felt layers, the increased pressure of the

warmed air/vapour mixture will force the roofing felts upwards forming a blister. Stretching the roofing membrane in this manner can damage its water tightness and probably cause leaking. Rain water penetrating the damaged roofing membrane leads to further deterioration of roofing, roof insulation and eventually the roof structure (Figure 4).

Recommendations

The extreme conditions to which the roof structure, and actually the whole building envelope of the swimming pool is exposed, can be documented by an example of an indoor pool building in the Ottawa area. The average air temperature registered for two weeks in January by a hygrothermograph placed inside the pool wall was 29.4°C and the registered relative humidity was 45%, giving a vapour pressure of 14 mm of mercury. By comparison, the average ambient water vapour pressure in Ottawa for the same period was 2.5 mm of mercury, resulting in a net outward vapour pressure of 11.5 mm. Such a difference in vapour pressure puts great demands on the quality and proper installation of a continuous vapour barrier at the warm side of insulation to control vapour diffusion into the structure. If the vapour barrier is not properly installed, punctured or otherwise damaged, the quantity of water vapour forced by pressure difference into the roofing system can be substantial. Formation of blisters in the roofing membrane can be extensive. Further, the area of the roof over a swimming pool hall has to be

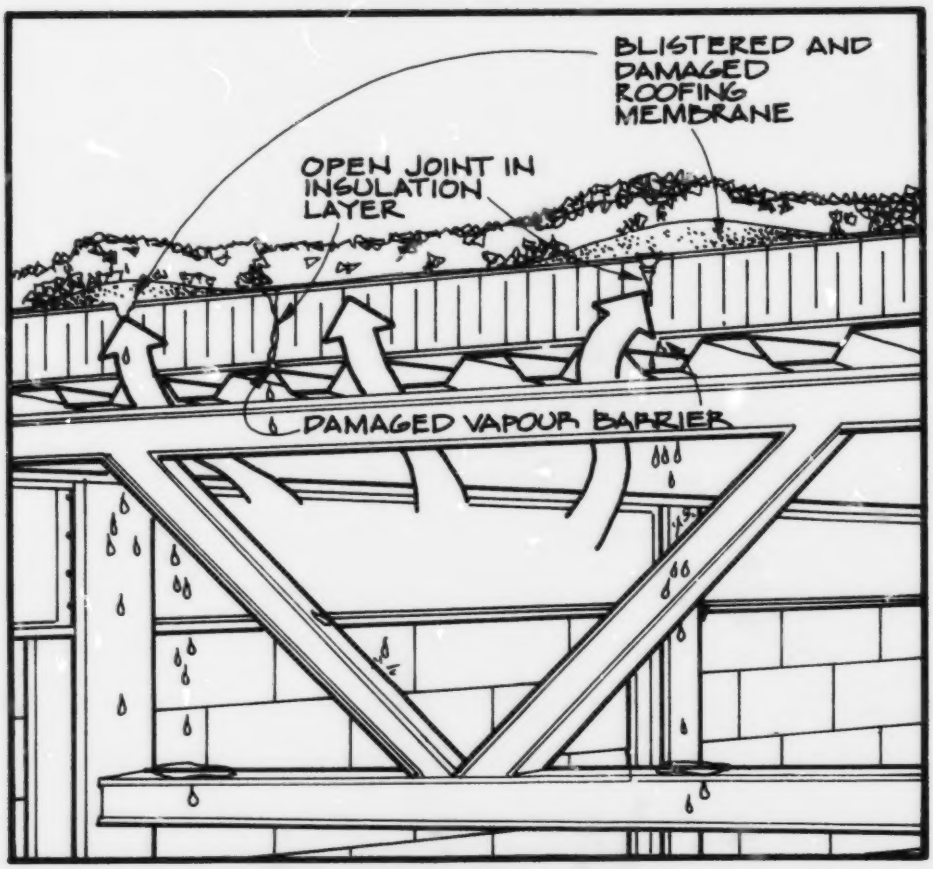

FIGURE 4. BLISTERS IN ROOFING MEMBRANE

considered. Unless adequate expansion joints with proper flashing etc., are provided in the design and executed in construction, the roofing membrane can be exposed to thermal stresses (caused by the differential movement of the structure) which are beyond its capacity. Roofing membrane can split or be torn away from the perimeter cant strips etc. Any damage of this sort naturally leads to deterioration of the roofing system, more retained water, leakage, and eventually to the complete ineffectiveness of the roof structure.

It is our considered opinion that the most suitable roofing for a flat roof over swimming pool halls is a well designed and well executed inverted roofing system (sometimes known as the "upside-down roof"). It utilizes the vapour barrier applied to the exterior face of the roof deck (be it wood, concrete or exterior type gypsum board panels attached to steel fluted roofing sheet). The roofing membrane is installed directly over it. The rigid plastic foam insulation is then placed on top of the membrane and weighted down by stone ballast. The location of the vapour barrier and the roofing membrane in direct contact with the roof structure allows for proper sloping of the membrane to drain. The insulation foam can be laid over the whole roof in full thickness (it does not have to provide the roof slope as it may have to do in other systems). Thus, the insulation value is kept uniform over the whole roof area and the roofing membrane is protected against

damage by the direct effects of the sun's radiation and temperature differences.

b) Problem 2 - Condensation of Moisture

Problems listed as Problem 2, Problem 3, Problem 4, Problem 5 and Problem 6 have a common cause - air movement and deposits of condensate.

Air movement into and out of buildings would be important not only in terms of the energy wasted in escaped heat, but for moisture carried and deposited within the building envelope. This moisture frequently leads to serious deterioration of materials. The phenomenon that produces this problem is the reduced ability of air to hold moisture in the form of water vapour as the temperature drops.

You could have heard the term "relative humidity of air". What does it mean and how does it affect the building? The amount of moisture, which the air is able to contain depends on its temperature. Higher temperature permits greater capacities of moisture in air. But, when this warm, humid air comes into contact with a cool surface it cools down to what is described as the "dew point temperature". At this point, the moisture contained in the air condenses into water (or ice if the temperature of the surface is below 0°C). The relative humidity at a given temperature is a ratio expressed as a percentage of the weight of water the air

actually holds to the maximum amount it could hold. When air is saturated with water vapour, the relative humidity is 100 per cent (100% RH).

Cold air leaking into a building because of lower pressures inside does not constitute a moisture problem. Even though the relative humidity inside may be close to saturation, the cold air coming in contains only small quantities of water vapour. As it is warmed, the water vapour originally contained in the air becomes a smaller and smaller portion of the amount that the air could contain. For example, air at -12°C and 100% RH (saturated) when heated to 29.4°C will have an RH of only 7 per cent. At this higher temperature air can hold about 14 times as much moisture as it did initially. Because the occupancy of most buildings produces moisture from various sources, the relative humidity of the warmed air is gradually increased. In swimming pools, which have large free surfaces of heated water, evaporation causes great increases in relative humidity.

In the upper parts of the building where the pressure differences between inside and outside are greatest, the warmed, more highly humidified air is driven outward through openings in the building envelope. As this happens, the air is cooled and the ability to hold water vapour diminishes. Without any further addition of moisture, its relative humidity goes up until it reaches 100% (saturation). When it is cooled below the saturation or dew-point temperature, the excess water vapour condenses on the colder surfaces of the walls or the roof.

For example, the dew-point temperature of air at 29.4°C and 45% RH is 16°C; this means that if it is allowed to leak into colder parts of the building shell, it will deposit some of its moisture by condensation on all surfaces colder than 16°C. Some of the water vapour will, of course, escape to the outside air, but much of it will be trapped within the building shell as water or frost (Figure 5).

What is, in this case, visible to the pool operator is only the condensation on the face of the exterior wall, slowly trickling down to the pool deck. If this increased moisture on the pool deck was the only result, the pool owner/operator could simply drain the excess from the deck by floor drains.

What of course usually happens is .....

Problem 3

...that the interior paint is peeling off the wall. This damage indicates a more serious problem. Moisture, carried in the humid air, was allowed to penetrate behind the wall paint system either by improperly applied paint, cracks in the block joints, or other damage, which the paint was not able to bridge and seal. The paint adhesion to the moist block surface deteriorates in time and there is probably efflorescence on the interior face of the wall, breaking the paint layer from the block surface (Figure 6).

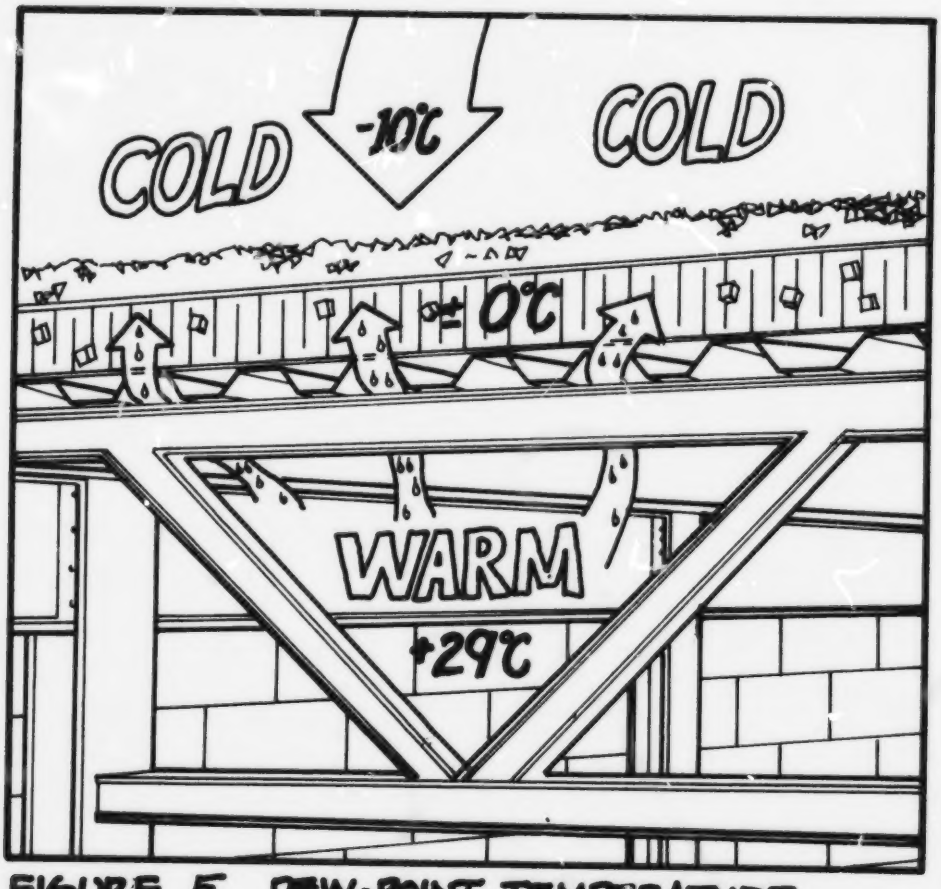

FIGURE 5. DEW-POINT TEMPERATURE

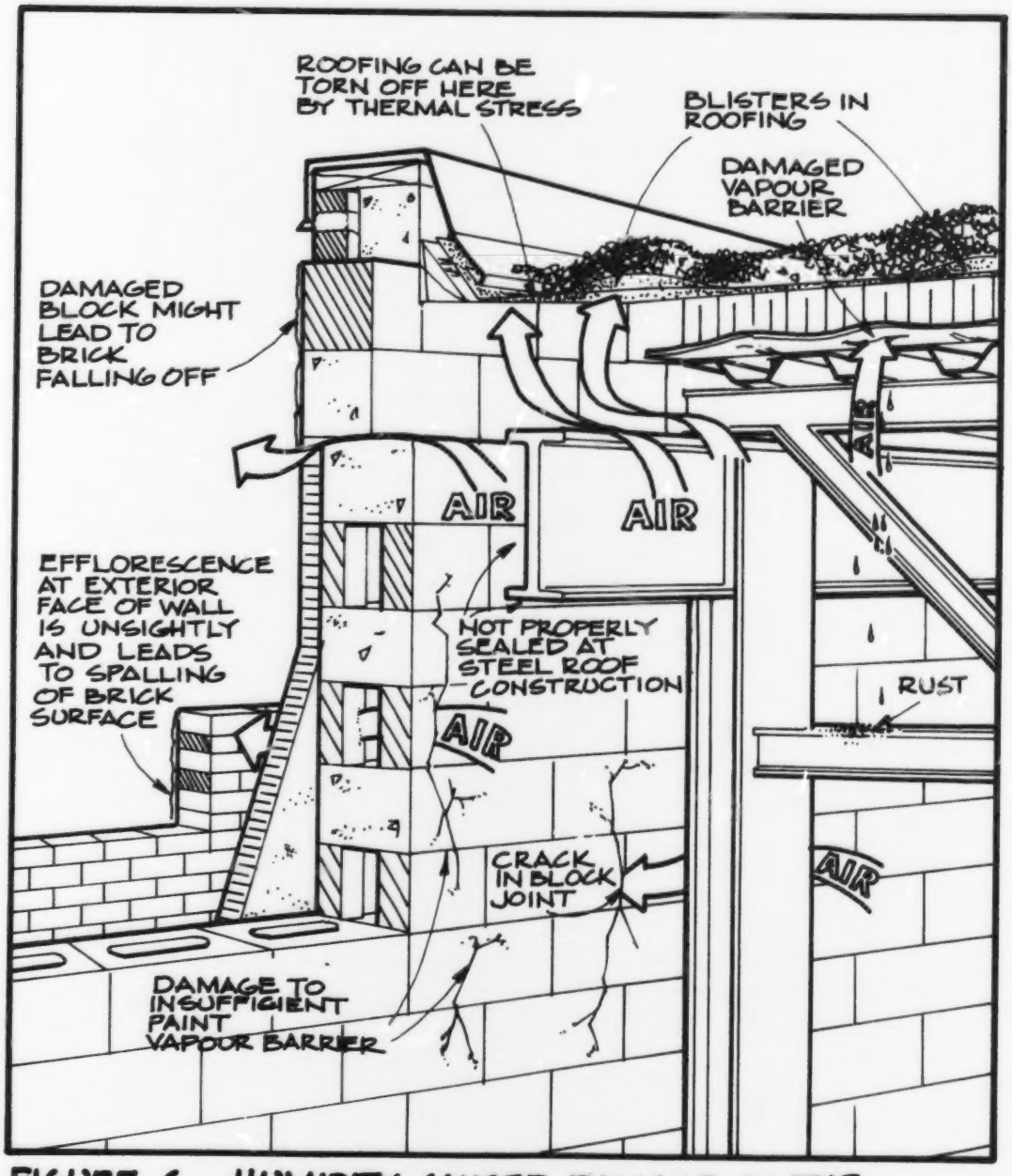
ROOFING CAN BE TORN OFF HERE BY THERMAL STRESS
BLISTERS IN ROOFING
DAMAGED VAPOUR BARRIER
DAMAGED BLOCK MIGHT LEAD TO BRICK FALLING OFF
AIR
AIR
EFFLORESCENCE AT EXTERIOR FACE OF WALL IS UNSIGHTLY AND LEADS TO SPALLING OF BRICK SURFACE
NOT PROPERLY SEALED AT STEEL ROOF CONSTRUCTION
RUST
AIR
CRACK IN BLOCK JOINT
AIR
DAMAGE TO INSUFFICIENT PAINT VAPOUR BARRIER

FIGURE 6. HUMIDITY CAUSED DAMAGE IN THE UPPER PART OF POOL BUILDING

As shown above, warm humid air coming in contact with a cooler surface deposits some moisture content in the form of condensate. In the case of peeling paint, part of the moisture is deposited on the paint surface, part of it is formed between the poorly adhering paint layer and the block interior face and the rest of the condensate forms in the block cavity. The capillary action spreads this water into the pores of the concrete blocks and the water migrates either towards the insulation layer within the wall cavity, or towards the inside face of the block. During migration, the water leaches out the salts contained in concrete and joint mortar. The visible results are white spots or powder crystals - called efflorescence - found under the peeled off paint film. Efflorescence on the interior wall face is usually most pronounced in the lower parts of the wall because of the effect of gravity on free flowing water.

Problem 4

.... or that the concrete blocks at the pool deck level are falling apart. The cause of this failure is the same as above. Migrating water within the block wall is drawn by gravity to the lower part of the wall resulting in efflorescence. When this cycle is repeated unchecked over the years, the effloresc ing salt crystals grow larger than the pores they are contained in and can cause spalling of the block surface (Figure 7).

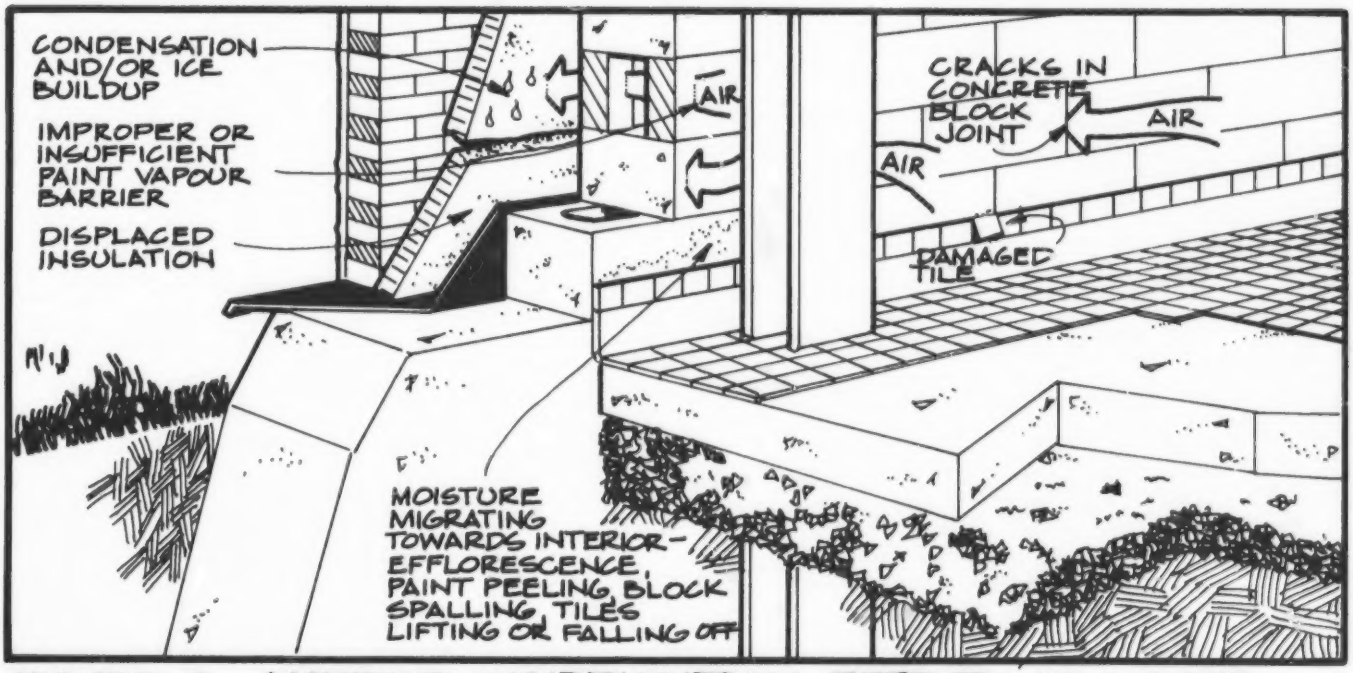
CONDENSATION AND/OR ICE BUILDUP
IMPROPER OR INSUFFICIENT PAINT VAPOUR BARRIER
DISPLACED INSULATION
AIR
CRACKS IN CONCRETE BLOCK JOINT
AIR
AIR
DAMAGED TILE
MOISTURE MIGRATING TOWARDS INTERIOR - EFFLORESCENCE, PAINT PEELING, BLOCK SPALLING, TILES LIFTING OR FALLING OFF

FIGURE 7. MOISTURE CONDENSATION EFFECTS IN LOWER PART OF EXTERIOR WALL

Problem 5

...the presence of efflorescence on the exterior face of the wall and the spalling of the brick or block facing has its cause once again in the infiltration of air and water vapour carried into the wall system (Figure 6). Main areas which can be suspected to be at fault are:

1) inferior interior paint systems, which in most pool buildings is supposed to act as the vapour barrier. The paint was found in many instances to be improperly applied or its continuity damaged by cracks in the wall - therefore ineffective as vapour barrier.
2) joints between the interior concrete blocks and steel columns embedded in block were not sealed, allowing free air movement from the pool arena into the wall cavity.
3) neither the space between the top row of concrete block and the bottom flange of the perimeter steel beam was sealed nor was there any attempt to seal at the joist/beam connection. The flutes at the underside of the corrugated steel roof deck were usually left open at the perimeter as well. Sometimes an attempt was made to seal these openings by means of cement mortar, but the mortar shrank and did not adhere well to steel, leaving enough space for air to penetrate into the wall cavity. In most cases, all three causes mentioned above, supply enough warm, moist air into the wall cavity to produce significant quantity of

condensate on the cold inside face of the exterior brick or block cladding. From its point of origin, condensated water by capillary gravity action, migrates to the outside face of the wall carrying soluble salts from mortar and brick/block material. The visible proof of a faulty construction - efflorescence - appears. Over the years, with the repetition of the freeze - thaw cycle, efflorescence then causes structural damage by spalling bricks or blocks.

Recommendations

The high relative humidity in the swimming pool building and the migration of moisture into the building structure discussed in Problem 2 can be understood as the main cause of problems described not only in Problem 2 but in Problem 3, Problem 4 and Problem 5.

Moisture condensed on the interior wall surface and within the exterior envelope structure can and will cause the sweating of the walls, peeling of paint, and deterioration of the masonry in the building and on its exterior. The only way to prevent this is to stop, effectively, the moisture penetration into the building envelope. The surface of the interior concrete wall block joints must be inspected for all deficiencies. The interior paint cannot be accepted only for its interior finish value. It is the first line of defence against moisture penetration. Properly cleaned and sealed surface of the concrete block and well tooled block joints free of any gritty protrusions are necessary. No cracks are

acceptable. A well executed paint system of a minimum 2 layers, preferably of different shade or colour, allowing for good inspection, is recommended. All structural joints, for instance between concrete block and steel supporting structure (if they cannot be avoided in design), must be sealed using material which allows for differential movement in the structure (block and steel expand and contract differently with temperature changes). Just filling these joints with mortar is not sufficient. All free space at the roof and exterior wall junction must be sealed.

Figures 8 and 9 show examples of how this problem was treated in a failing indoor pool building. The necessary seal of openings in the wall was achieved by spraying the affected areas with polyurethane foam foamed in place after the surfaces were cleaned and treated to the foam manufacturers requirements for proper adhesion. In places where the foam treatment was visible to the pool users and could be damaged, the excessive foam was then cut off and painted over. In the roof space, it was left as foamed.

The paint system in the same building was found well executed, up to approximately 3 m, above the pool deck. The upper part of the wall - above the reach of the casual inspection from the pool deck level was another matter. The block was evidently not properly prepared for paint and in comparison with the lower part of the wall it was obvious that only one layer of paint was applied. The owner in this case decided to apply acoustic treatment to the exterior wall. Because the application of this

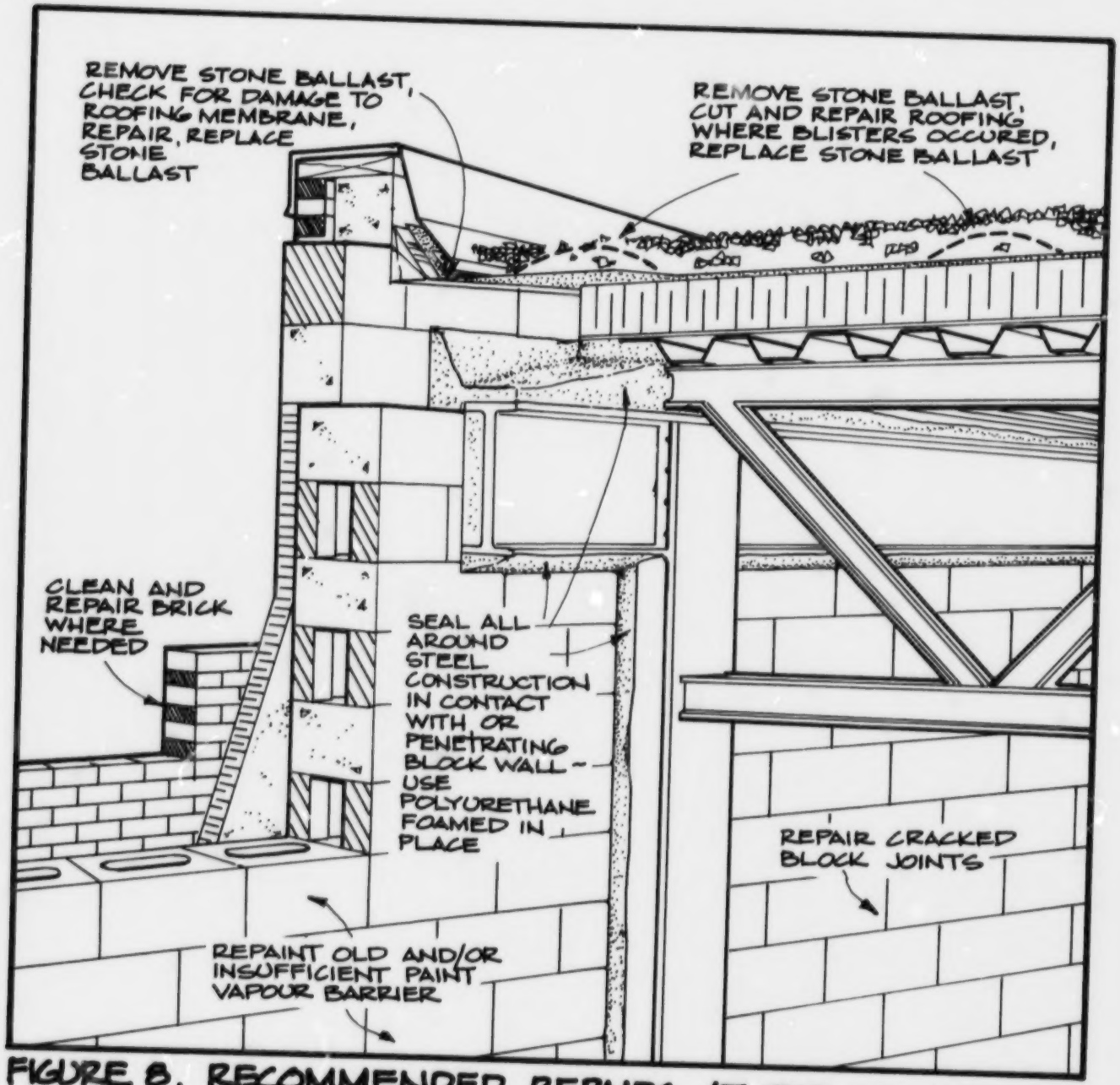
REMOVE STONE BALLAST, CHECK FOR DAMAGE TO ROOFING MEMBRANE, REPAIR, REPLACE STONE BALLAST
REMOVE STONE BALLAST, CUT AND REPAIR ROOFING WHERE BLISTERS OCCURED, REPLACE STONE BALLAST
CLEAN AND REPAIR BRICK WHERE NEEDED
SEAL ALL AROUND STEEL CONSTRUCTION IN CONTACT WITH OR PENETRATING BLOCK WALL - USE POLYURETHANE FOAMED IN PLACE
REPAIR CRACKED BLOCK JOINTS
REPAINT OLD AND/OR INSUFFICIENT PAINT VAPOUR BARRIER

FIGURE 8. RECOMMENDED REPAIRS AT TOP OF EXTERIOR WALL AND ROOF

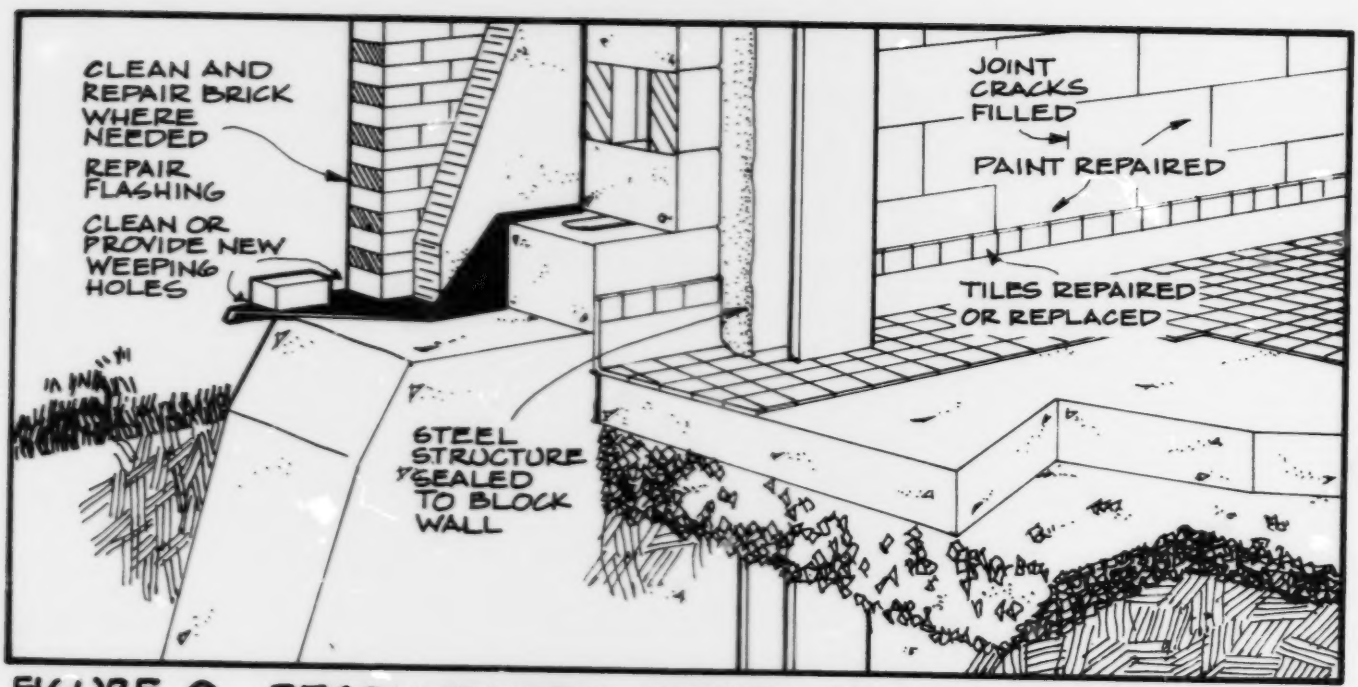
CLEAN AND REPAIR BRICK WHERE NEEDED
REPAIR FLASHING
CLEAN OR PROVIDE NEW WEEPING HOLES
JOINT CRACKS FILLED
PAINT REPAIRED
TILES REPAIRED OR REPLACED
STEEL STRUCTURE SEALED TO BLOCK WALL

FIGURE 9. RECOMMENDED REPAIRS AT LOWER PART OF EXTERIOR WALL

material required full face treatment of the area by a proprietary sealant before the sound insulation application, it was accepted that the sealant would perform as sufficient vapour barrier, and the paint was not repaired. Otherwise an additional coat of paint would have been necessary.

After all the described remedial work was done, the exterior surface of the brick facing was cleaned of all signs of efflorescence by a solution of muriatic acid. (Note: Muriatic acid solution should be applied by an experienced contractor and after the work is finished the wall must be washed with water!)

It can be reported here that even when the building originally suffered all the damage described above, (efflorescence, paint peeling, damage to interior block and to exterior brick) within two years after application, the remedial sealing of the joints, cracks, etc., and provision of a vapour barrier in the full height of the exterior wall appeared to solve the problems. No more damage of the type described was visible in four years of pool operation after the repairs were executed.

c) Problem 6 - Rusting of Metal Elements

The severity of the corrosive action caused by the humid environment in the pool area, and in many cases even in the rest of the building, is increased by the presence of chlorine vapours in the air. Chlorine enters the pool hall air by water evaporation

from the pool surface. The exposed steel structural members should have been treated against this attack before or at the time of construction by heavy galvanizing or proper anticorrosive paint. Inspection by the owner/operator is necessary at periodic intervals to find how the protective coatings are performing. Immediate repairs of localized coating failures must be executed. Otherwise, when the whole structure is found rusted it means, in the best of cases, sandblasting the structural members and providing the new protective coating. This work is not only costly by itself but would also require closing the facility for a longer period of time while the repairs are conducted. Localized repair can usually be performed by maintenance staff during the off hours.

Recommendations

Rusting, of metal elements of the building outside the swimming pool hall, caused by the corrosive nature of moist air containing chlorine vapours, can be easier remedied. Creating "air-lock" compartments at the entry to the pool area can cut down on moist air infiltration into the rest of the building. This might mean just installing two sets of weatherstripped doors in the corridor leading to the pool.

A more effective, though probably more expensive solution would be pressurizing the "dry" areas of the building against the "wet" area of the pool enclosure. It might be possible to achieve this

goal by adjusting the controls of the existing ventilating system. A heating system expert must be consulted.

Door frames, metal doors, lockers, and metal toilet and shower partitions, etc., which might, in the owner/operators opinion, be rusting prematurely were probably bought "from the lowest bidder" without consideration given to the kind of environment in which they were to be installed. Only frequent maintenance and painting with anticorrosive paint could help in this case.

The Canadian Sheet Steel Building Institute in its "Owner's Guide to Maintaining Recreation Buildings" suggests the following paint maintenance:

Structural Members

Structural members should be inspected annually for signs of corrosion (rusting). A building, such as a pool enclosure with its high internal humidity, can experience corrosion problems due to the condensation of humidity on the structural members. This phenomenon can be more serious in pools where the condensate has a high percentage of chlorine. If the structural members show signs of rusting, they should be coated with a rust inhibitive paint suitable for application to structural steel and to the existing coating material.

Cleaning Pre-finished Sheet Steel

An occasional thorough cleaning of pre-finished material can extend the service life and help to maintain the appearance of the finish. Simply washing with water, using hoses or pressure sprays, is often sufficient. Waxing is an additional method of prolonging the service life of pre-finished material.

In areas where heavy dirt deposits dull the surface, a solution of water and detergent may be used: 100 ml (1/3 cup) of a typical laundry power detergent per 4 litres (1 gallon) of water. A soft bristle brush should be used for scrubbing followed by a clear water rinse.

Mildew may occur in areas subject to high humidity. To remove mildew along with the dirt, the following is suggested:

100 ml (1/3 cup) laundry detergent

200 ml (2/3 cup) trisodium phosphate (TSP)

1 litre (1 quart) 5% sodium hypochlorite solution (laundry bleach)

3 litres (3 quarts) water

Use in a well ventilated area. A clear water rinse should follow.

Solvent and abrasive cleaners should be avoided. Caulking compounds, oils, grease, tars, wax and similar substances can be removed with mineral spirits applied only to the areas that are affected. Detergent cleaning and a thorough rinsing should follow the use of solvent.

Painting

There are a number of different applications for paint systems in a pool enclosure. There is the painting of the structural members, painting the sheet steel cladding (both inside and outside), and painting of the other fixtures inside the building (e.g. seats, floors, partitions).

Selection of a paint for the building fixtures depends upon the application, but usually a brand name household or commercial paint would be adequate. This paint is intended basically for appearance and not for providing corrosion protection.

The main structural members, as well as the secondary structural members, need to be coated with a rust inhibitive paint unless they are protected with a metallic coating (such as zinc) or a special protective coating. Any painting schedule should try to inspect and touch-up all of the steel members, not just those places that are easily accessible.

The painting of sheet steel cladding can, in some cases, pose a particular problem. Basically, there are two painting requirements that arise: (1) the cladding was supplied prepainted, and after a number of years in service, the paint requires a touch-up in places or a complete repainting; or (2) the sheet steel cladding was supplied unpainted with the intention of painting after installation.

When repainting over existing prepainted cladding, a number of factors should be considered in order to achieve the best results.

(1) It is important to select a primer that is compatible with the existing paint system. Most often in eastern Canada, sheet steel cladding for recreational buildings is supplied with a modified silicone polyester paint system. A paint manufacturer should be consulted for advice regarding selection of the proper paint system for repainting.

(2) Before painting, the surface must be cleaned of all dirt, rust, or other substances.

(3) The paint should be applied in strict accordance with the directions of the paint supplier.

(4) When choosing a colour, consider that a lighter colour will last longer on roofs since the lighter colour will better resist the harmful effects of the sun. Aesthetic considerations, however, often dictate that dark colours be used on roofs. In doing so, the owner must accept that the roof will likely fade faster and need to be repainted more frequently than if a light colour is used.

(5) When only a touch-up is required, keep the touch-up to a minimum since this paint will not last as long as the original paint system. A small artist's brush or air brush should be used to apply the paint to a small surface.

Field painting of galvanized sheet steel after installation can create problems in many buildings. Unpainted galvanized sheet steel supplied by Canadian steel mills is typically coated with a chemical passivation treatment intended to control what is called wet storage stain (also known as "white rust"). White rust can occur where the galvanized material is subject to certain temperature and humidity, commonly occurring when the formed panels are stacked at the construction site waiting to be erected. White rust is, essentially, corrosion products of the zinc coating and will eventually lead to the rusting of the steel if it is allowed to continue. To control this problem, the passivation treatment is regularly applied to the unpainted sheet steel. The passivation, however, has a limited effectiveness; therefore, the outdoor storage of sheet steel products onsite, awaiting erection, should be as brief as possible.

If a sheet steel product is to be field painted after erection, it is necessary to specify that the galvanized material be supplied unpassivated. The manufacturer will then order this material from the steel mill and fabricate the product. Galvanized material supplied this way can then be painted using an appropriate paint system and application procedure. Galvanized sheet steel that has been supplied without specifying that it be unpassivated cannot reliably be painted. With a few exceptions, paint will not adhere to

passivated sheet steel and often flakes off after a short time, especially in a humid environment. There are specialized paint systems available that can be used, but the proper application of these paints is important and there is likely to be an additional cost. Any owner who is thinking of field painting galvanized sheet steel products should be careful in selecting the proper paint system and application methods.

d) Problem 7 - High Energy Bill

Insufficient insulation of the building causes various condensation effects discussed above. Many operators try to decrease the humidity in the pool wall by increased ventilation or extraction of humid air to the outside. This means more fresh air has to be brought in and heated to achieve the necessary level of comfort in the pool area. If the air is not heated enough, it reduces the temperature of the pool water just by coming into contact with it. The more of this cooler air that is forcibly moved through the pool hall, the more the water is cooled, creating higher demand on the heating plant.

Recommendations

There are reasons for the complaints about high heating bills for pool water and hopefully, remedies. The cooling effect of the air movement across the water surface has been mentioned. In a telephone survey, conducted during preparation of this report, we

came across two cases, where the operators reported the relative humidity, measured at the pool deck level, as 20% RH and 30% RH respectively. If this is true, and their recording equipment was not by any means faulty, it would mean that they are exhausting extreme quantities of air from the pool area. Combine the cost of warming the water with the cost of heating of fresh air and the total bill will be a burden to any operator.

A more positive picture comes from a report of another municipal pool operator. Originally the pool area air and the pool water were heated by gas-fired equipment. The pool hall was mechanically ventilated to remove extensive humidity. At this time the temperature of the air in the pool hall was kept at 30.0°C, water temperature at 27.8°C and the air relative humidity moved from 62% RH to 70% RH. As an energy saving measure a dehumidifying equipment capable of heat recovery (the heat present in the extracted humid air is retained and used to warm the incoming fresh air and pool water) was eventually installed. The reported values after installation of this equipment were: air temperature 30°C, water temperature 29°C relative humidity of the air 52 - 55% RH. Notice that the water temperature was increased by 1.2°C for increased comfort of the users. Even when the cost of this equipment was well in excess of $100.000 the calculated cost recovery is five to six years in operating costs alone. Additional benefits can be seen in lowering the relative humidity of the air

(i.e. the problems discussed previously), and problems will now be less pronounced or will not occur at all.

Another cost saving feature is the use of a pool blanket, which is placed on the pool water after operating hours and removed before the pool is used again. The use of the pool blanket not only cuts down on evaporation from the pool (i.e. it decreases the relative humidity of the pool hall air and in this way reduces the necessary ventilation costs), but more importantly it allows lowering the pool space temperature when the pool is not used, without lowering the temperature of the water as a result. The costs for installation of a pool blanket including controls on the heating equipment etc. are estimated to be recovered in energy savings over approximately two years (Figure 10).

CONCLUSION

High humidity is a problem facing managers of indoor pools. It is not a problem that can be ignored. Clearly, steps must be taken to deal with, not only the symptoms, but also the actual source of the problems.

We hope this paper assisted in identifying a number of causes and possible solutions to common problems that occur in pools due to high humidity levels. Properly planned maintenance programs and early attention to problems will reduce long term operational costs and help you in extending the life of your pool.

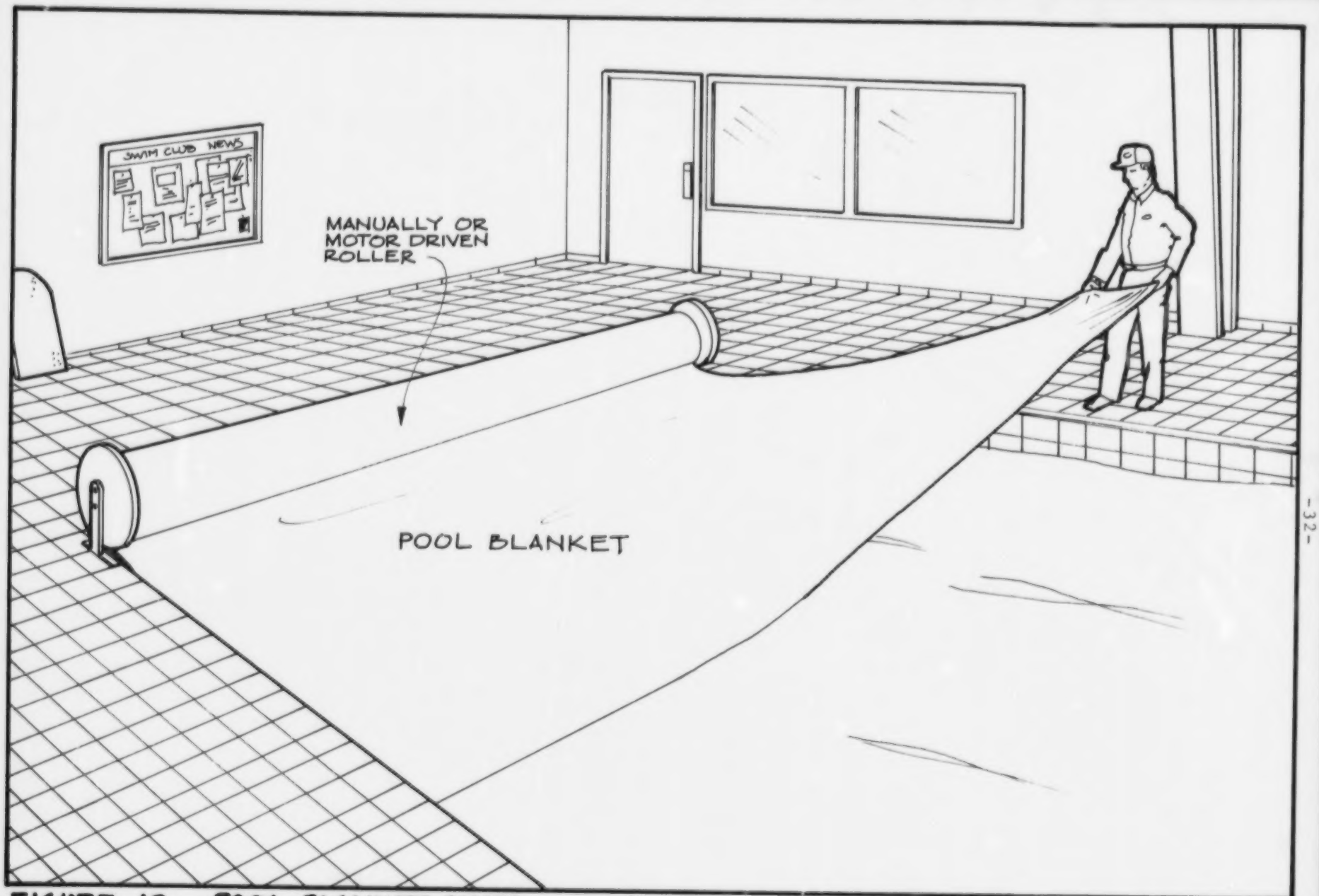

FIGURE 10. POOL BLANKET COVER